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Hybridization gap in Kondo insulators CeRhAs and CeRhSb studied by ultrahigh-resolution photoemission spectroscopy

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Ultrahigh-resolution photoemission spectroscopy ($\Delta E \sim 8$ meV) has been performed on CeRhAs and CeRhSb to study the mechanism of (pseudo)gap formation in the Kondo insulators. Using the difference in the photoionization cross section between Ce $4f$ electrons and conduction electrons, we have successfully separated the Ce $4f$ from the conduction-electron partial density of states (DOS) in the spectra. We found that the both conduction-electron-derived and $4f$-derived DOS show a depletion (pseudogap) at E_F in contrast to metallic Kondo materials. With increasing the temperature, these pseudogaps gradually disappear by filling with additional intensity within the pseudogap, reflecting the temperature induced metal-insulator transition in CeRhAs and CeRhSb. It was also found that the size of f-pseudogap is always smaller than that of conduction electrons (c-pseudogap) while both scale well with the Kondo temperature. These results are qualitatively consistent with the theoretical prediction from the Anderson lattice model at half-filling, indicating that the hybridization between $4f$ and conduction electrons near E_F is essential for the Kondo gap in the Ce-based compounds.